

# CLEAN ENERGY SYSTEMS

**Carbon-Negative Energy  
Renewable Hydrogen Project  
An Opportunity for California**  
16 September 2020

ICEPAG 2020

*A Virtual Colloquium*

Hydrogen: A Platform for Sustainability

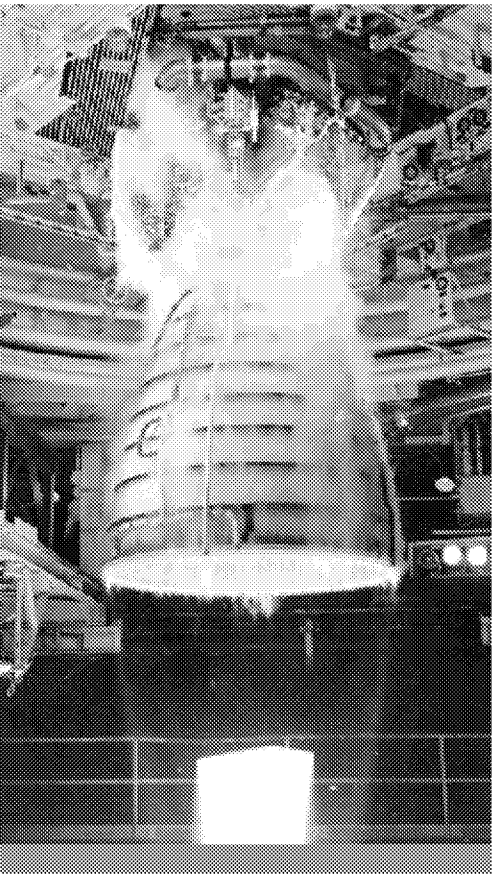
Smart Grid | Mobility | Electricity | Storage | Economics | Microgrids

September 14, 15, 16, 2020 | UC Irvine



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# CES | COMPANY BACKGROUND & OVERVIEW



- Founded in 1993 by former Aerojet aerospace engineers
- Corporate engineering and headquarters in Sacramento area
- Kimberlina test facility, a former 5 MW biomass power plant (Bakersfield, CA)
- Initial \$75,000 funding provided by the CEC leveraged more than \$140 million deployed to date
- Focused on enabling technologies for advanced clean energy solutions
  - Oxy-fuel (O-F) pressurized direct and indirect steam gas generators and reheat combustors – modified rocket engines
  - O-F turbines (OFTs) with development partners

# CARBON NEGATIVE ENERGY

## WHAT IS CNE?

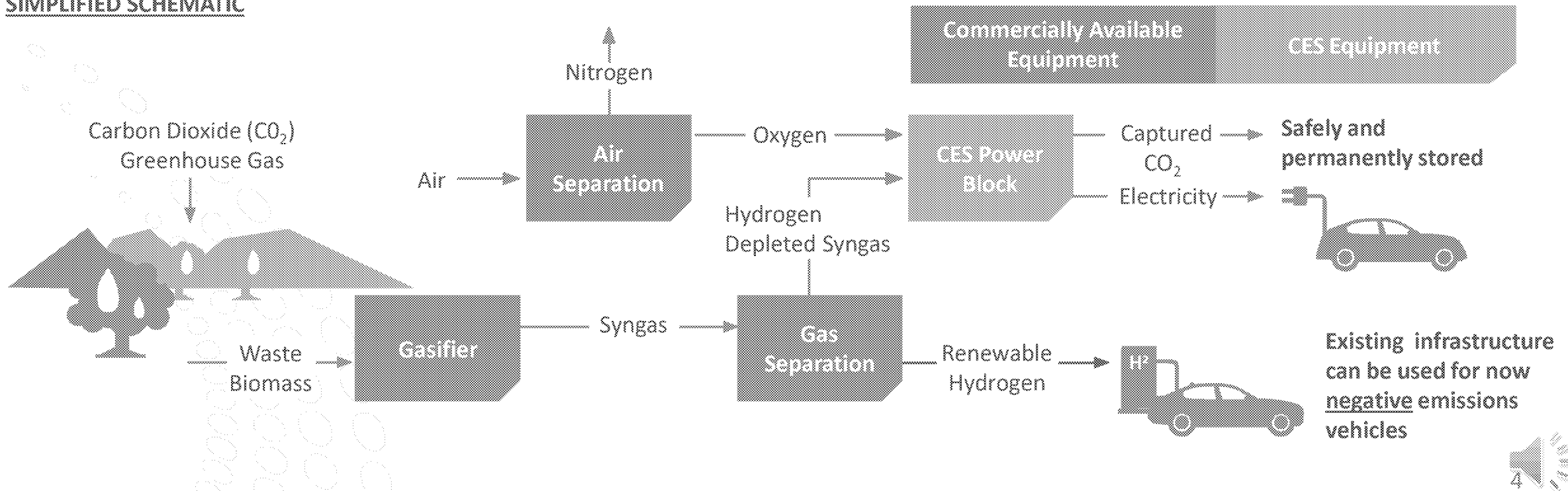
- **Carbon removal** refers to any process or system capable of removing and sequestering carbon from the air over its life cycle
- **CNE (or BioCCS)** refers to any bioenergy process that captures and permanently stores carbon safely underground through carbon capture and storage (CCS)
- CNE can remove the harmful greenhouse gas carbon dioxide ( $\text{CO}_2$ ) from the atmosphere while producing electricity and **clean, renewable hydrogen**



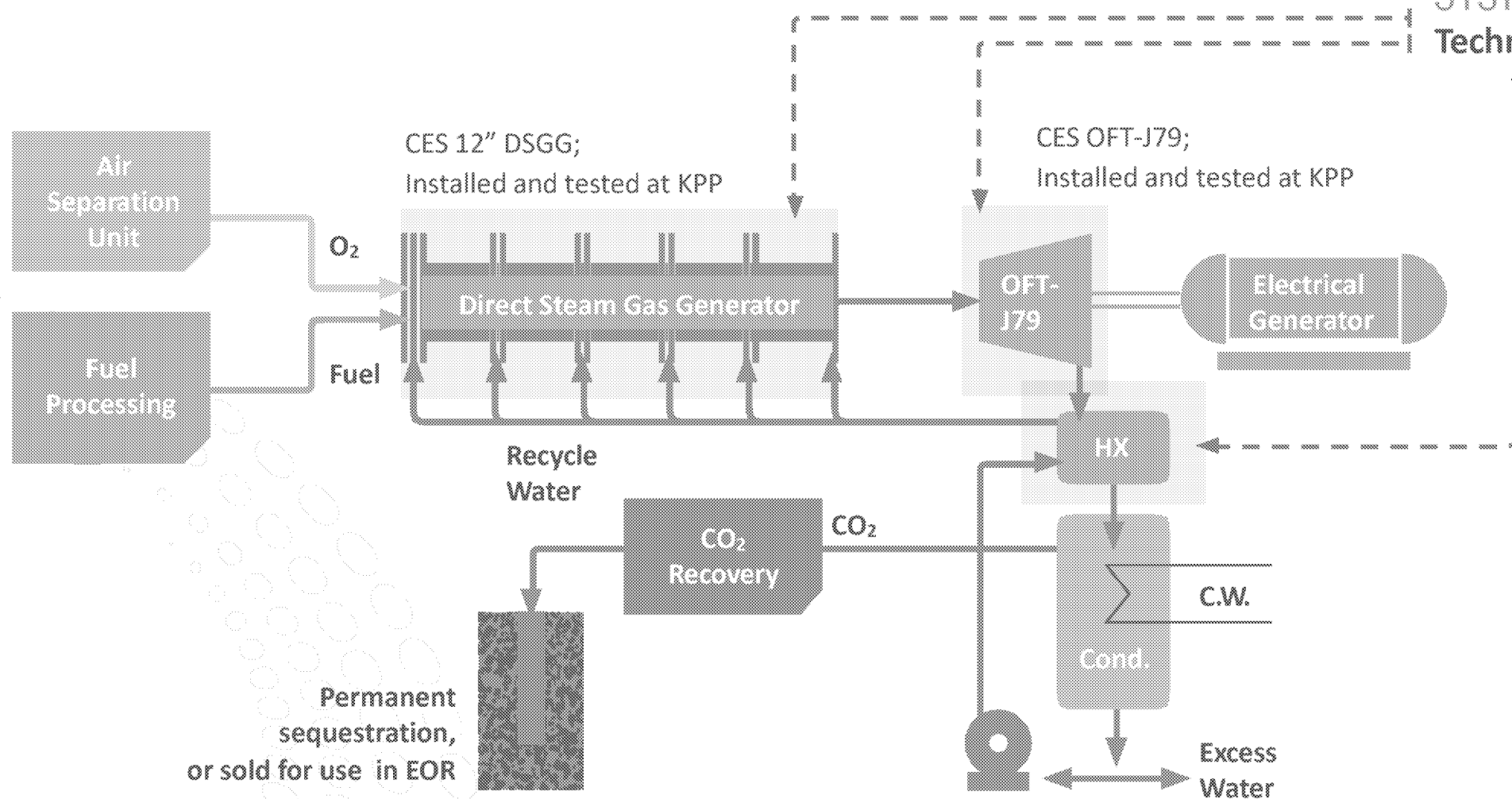
# CNE | HOW IT WORKS

CES Carbon Negative Energy (CNE) plants use waste biomass fuels that are gasified to produce a synthesis gas. This “syngas” is then used to produce renewable hydrogen (RH<sub>2</sub>), and/or electricity with full carbon capture using proprietary oxy-combustion technology

## SIMPLIFIED SCHEMATIC



# CNE | CES POWER BLOCK



\*See [www.CleanEnergySystems.com](http://www.CleanEnergySystems.com) for info on CES technologies

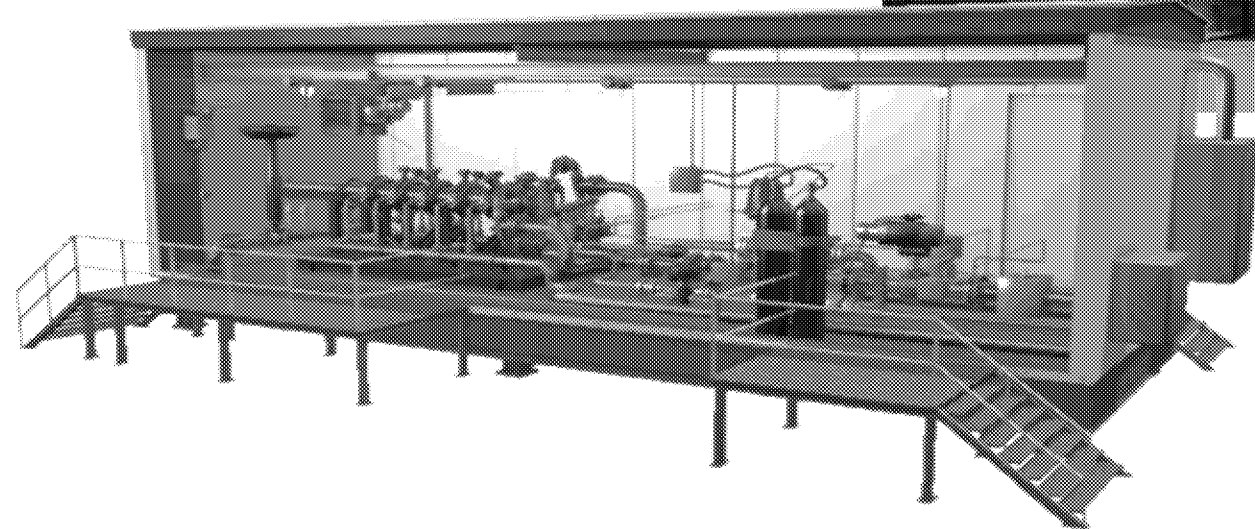
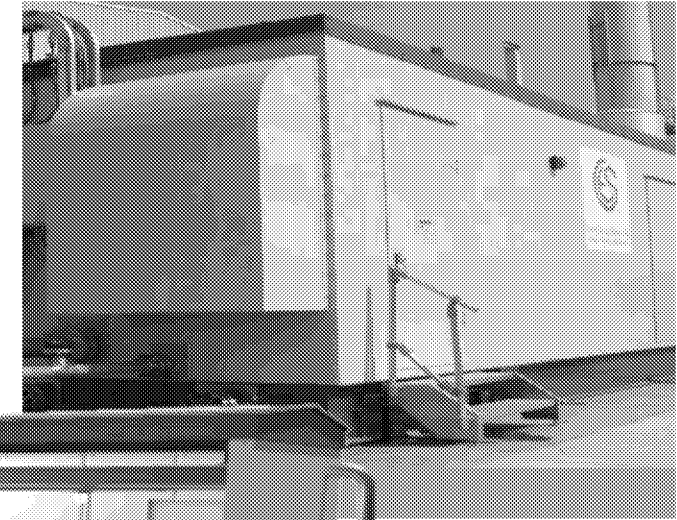
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# CES I DIRECT STEAM GAS GENERATOR PACKAGE

Fully containerized oxy-combustion system for easy transport and installation

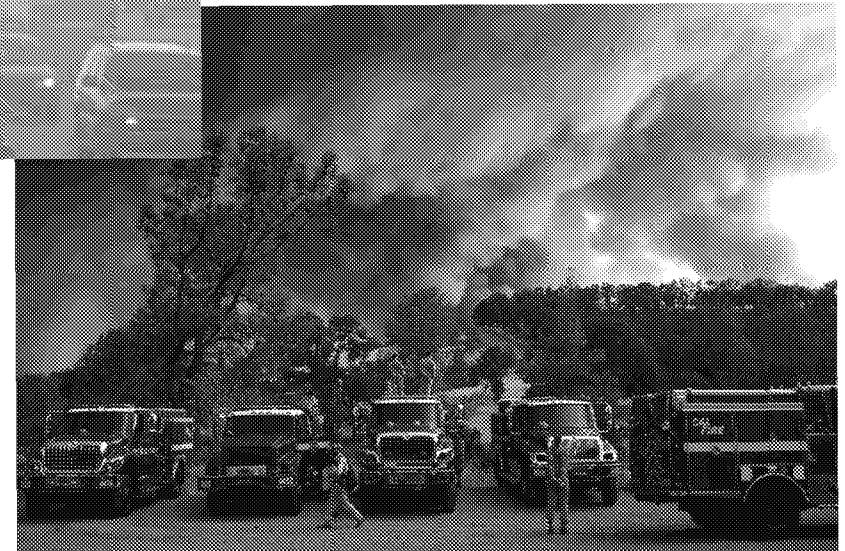
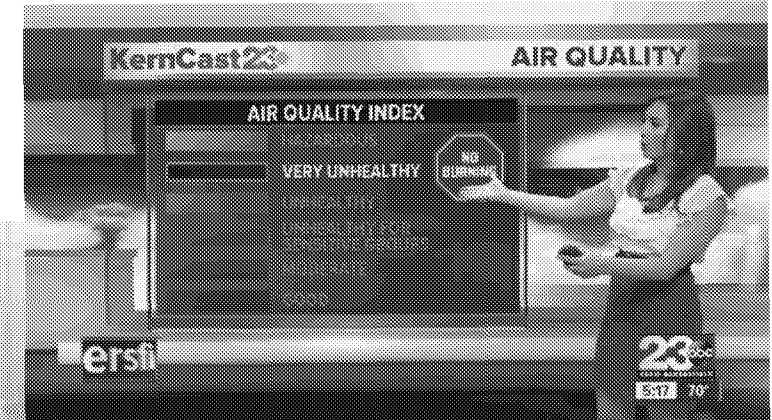
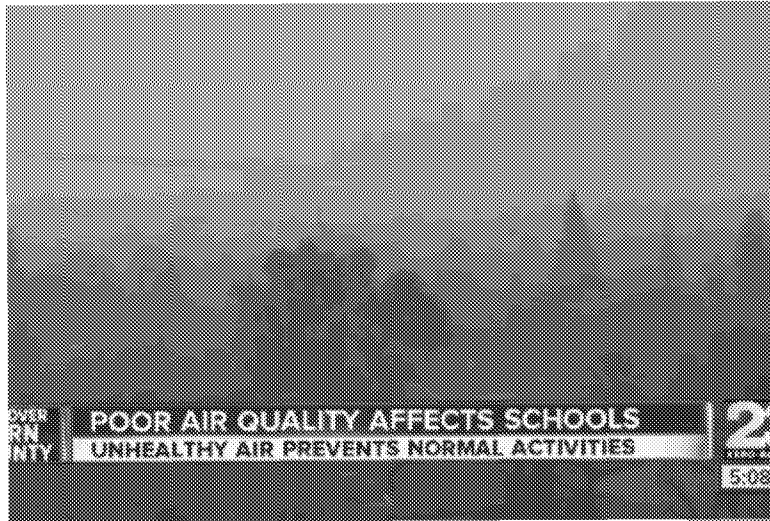
- **Combustor:** 2 meters (6 feet) long with 30 cm (12 inch) internal diameter
- **Container:** 3.3 meters (11 feet) x 3.3 meters (11 feet) x 12 meters (40 feet)
- Fits on standard shipping vehicles
- Designed and built to ASME Section VIII, Division 1
- Fully automated fire detection and suppression system
- Includes video monitoring and surveillance
- Minimized install time and cost





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# CNE: WHY NOW? CLIMATE CHANGE AND AIR QUALITY



## 2019 American Lung Association “State of the Air” Report

### Top 10 Most Polluted U.S. Cities:

Ozone	Short-Term Particle Pollution (24-hour PM <sub>2.5</sub> )	Year-Round Particle Pollution (Annual PM <sub>2.5</sub> )
1 Los Angeles-Long Beach, CA	1 Bakersfield, CA	1 Fresno-Madera-Hanford, CA
2 Visalia, CA	2 Fresno-Madera-Hanford, CA	2 Bakersfield, CA
3 Bakersfield, CA	3 Fairbanks, AK	3 Fairbanks, AK
4 Fresno-Madera-Hanford, CA	4 San Jose-San Francisco-Oakland, CA	4 Visalia, CA
5 Sacramento-Roseville, CA	5 Missoula, MT	5 Los Angeles-Long Beach, CA
6 San Diego-Chula Vista-Carlsbad, CA	6 Yakima, WA	6 San Jose-San Francisco-Oakland, CA
7 Phoenix-Mesa, AZ	7 Los Angeles-Long Beach, CA	7 Pittsburgh-New Castle-Weirton, PA-OH-WV
8 San Jose-San Francisco-Oakland, CA	8 Salt lake City-Provo-Orem, UT	8 El Centro, CA
9 Houston-The Woodlands, TX	9 Seattle-Tacoma, WA	9 Cleveland-Akron-Canton, OH
10 New York-Newark, NY-NJ-CT-PA	10 Pittsburgh-New Castle-Weirton, PA-OH-WV	10 Medford-Grants Pass, OR





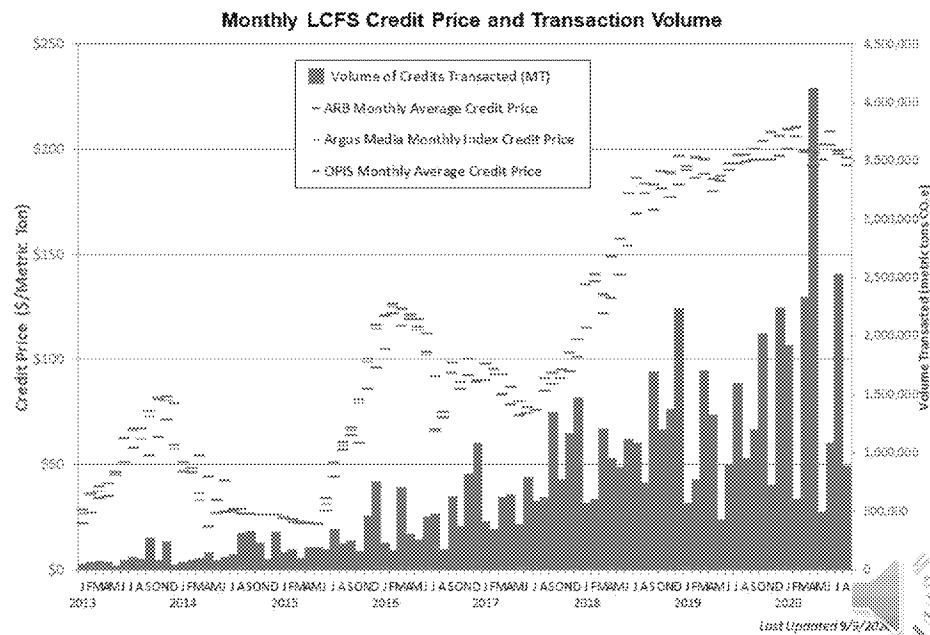
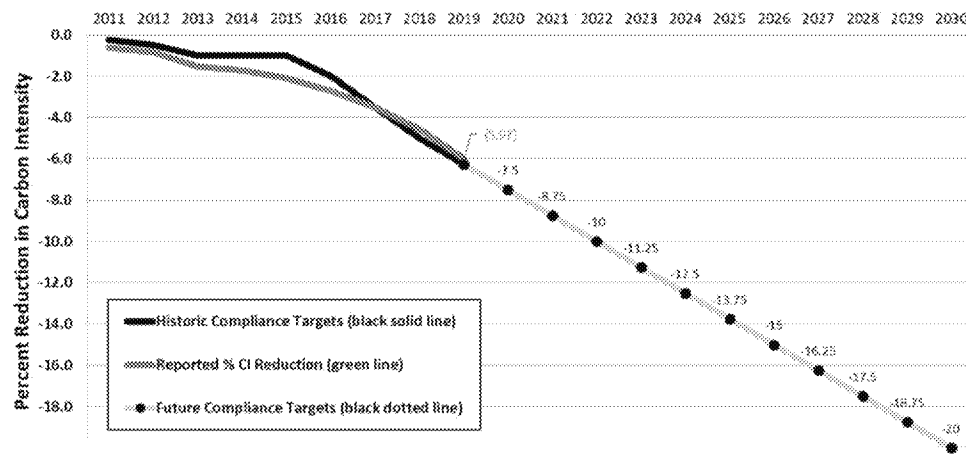
# CNE | WHY NOW?

## Multiple factors aligned to make deployment profitable

- Revenues for carbon capture and storage projects have increased from \$20 to \$250/tonne in select markets
  - Federal Tax Credit increased from \$20/tonne CO<sub>2</sub> to \$50/tonne CO<sub>2</sub>
  - California's Low Carbon Fuel Standard (LCFS) program credit prices consistently average near \$200/tonne cap\*
- Biomass power industry in California has collapsed due to competition from wind and solar for new power contracts
  - Resulted in stranded assets and infrastructure
  - Biomass waste disposal now a significant challenge for farmers and municipalities; attractive long-term fuel contracts available
- Enormous potential for carbon storage in California; projects build on knowledge gained from past efforts (e.g. CEC, DOE WestCARB)
- Required CES technology has been developed and vetted over the past 25 years → Low Technology Risk

\*\$200/tonne cap set in 2016 (later years adjusted for inflation)

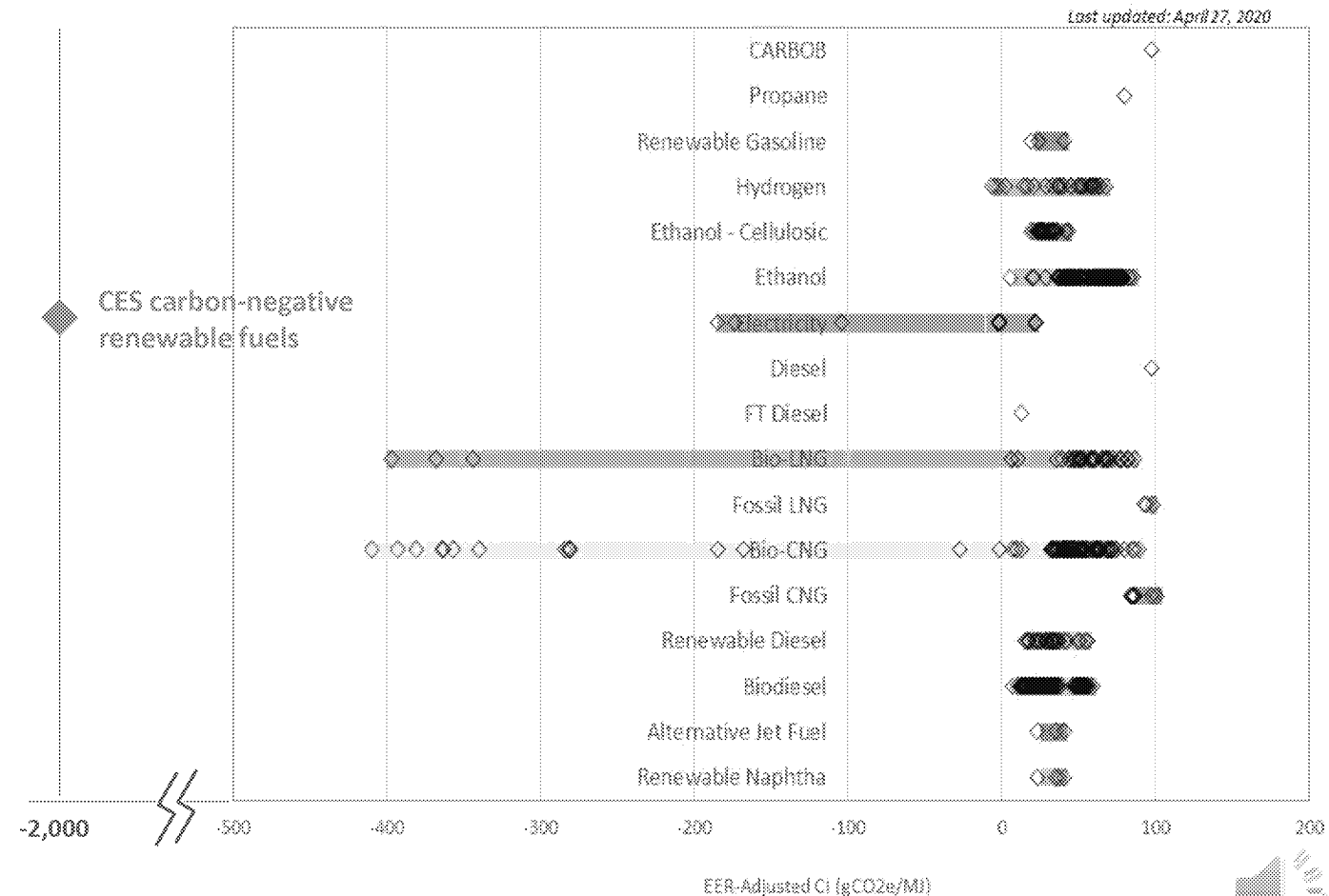
## California's Declining Carbon Regulation



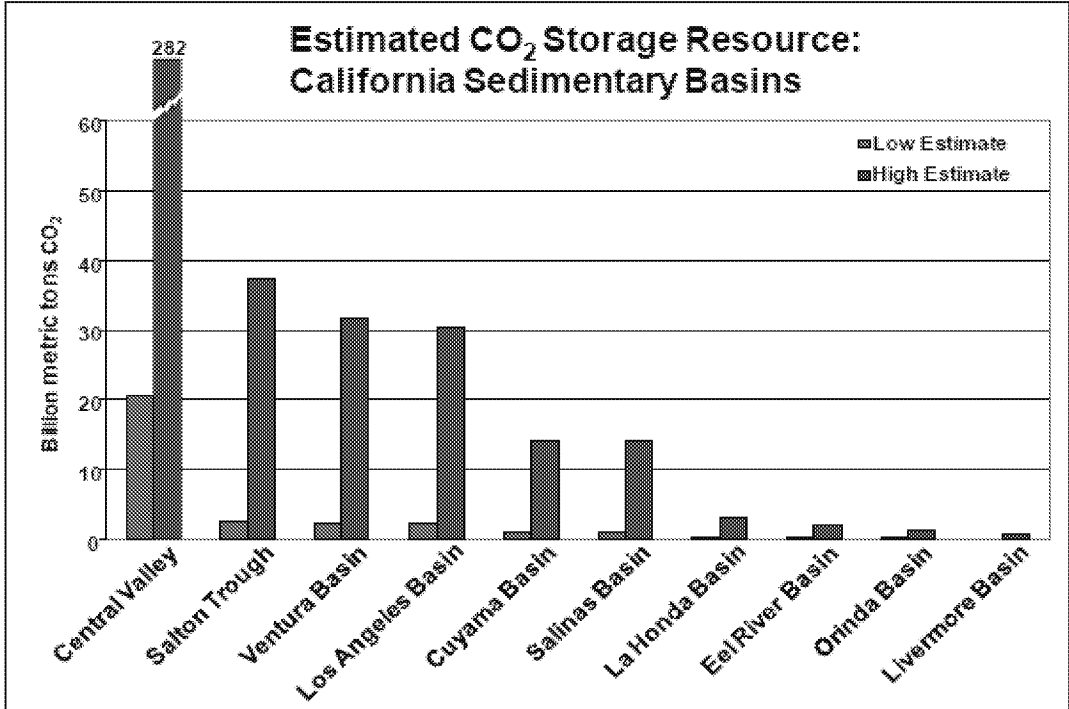
# CNE | GAME CHANGING RENEWABLE FUELS

- Transportation fuels certified to a “well-to-wheels” carbon footprint, known as a Carbon Intensity (CI)
  - Different fuel types can be compared directly using CO2 equivalent (CO2e) and energy economy ratio (EER) factors
- CES’ CNE plants will set a new precedent for carbon footprint of renewable fuels production
  - CNE fuels, e.g. electricity or hydrogen, have a CI score near -2,000 gCO2e/MJ (verified by an independent third party); 10 times better than nearest competitor!
  - CI score of CNE fuels is literally off the chart
  - Enabled by CES’ proprietary oxy-combustion technology and carbon capture and storage
  - Adds significant value in LCFS market

Carbon Intensity Values of Current Certified Pathways (2020)



# CNE | POTENTIAL FOR CCS IN CALIFORNIA



## California Offers Very Large CO<sub>2</sub> Storage Capacity:

- California's on-shore sedimentary have capacity for roughly 1,000 years of current CO<sub>2</sub> emissions (point source)
- The largest storage capacity identified in the state's Central Valley basin

30–460 Gt onshore saline formation capacity  
3.3–5.7 Gt natural gas reservoir capacity  
1.4–3.7 Gt oil reservoir capacity

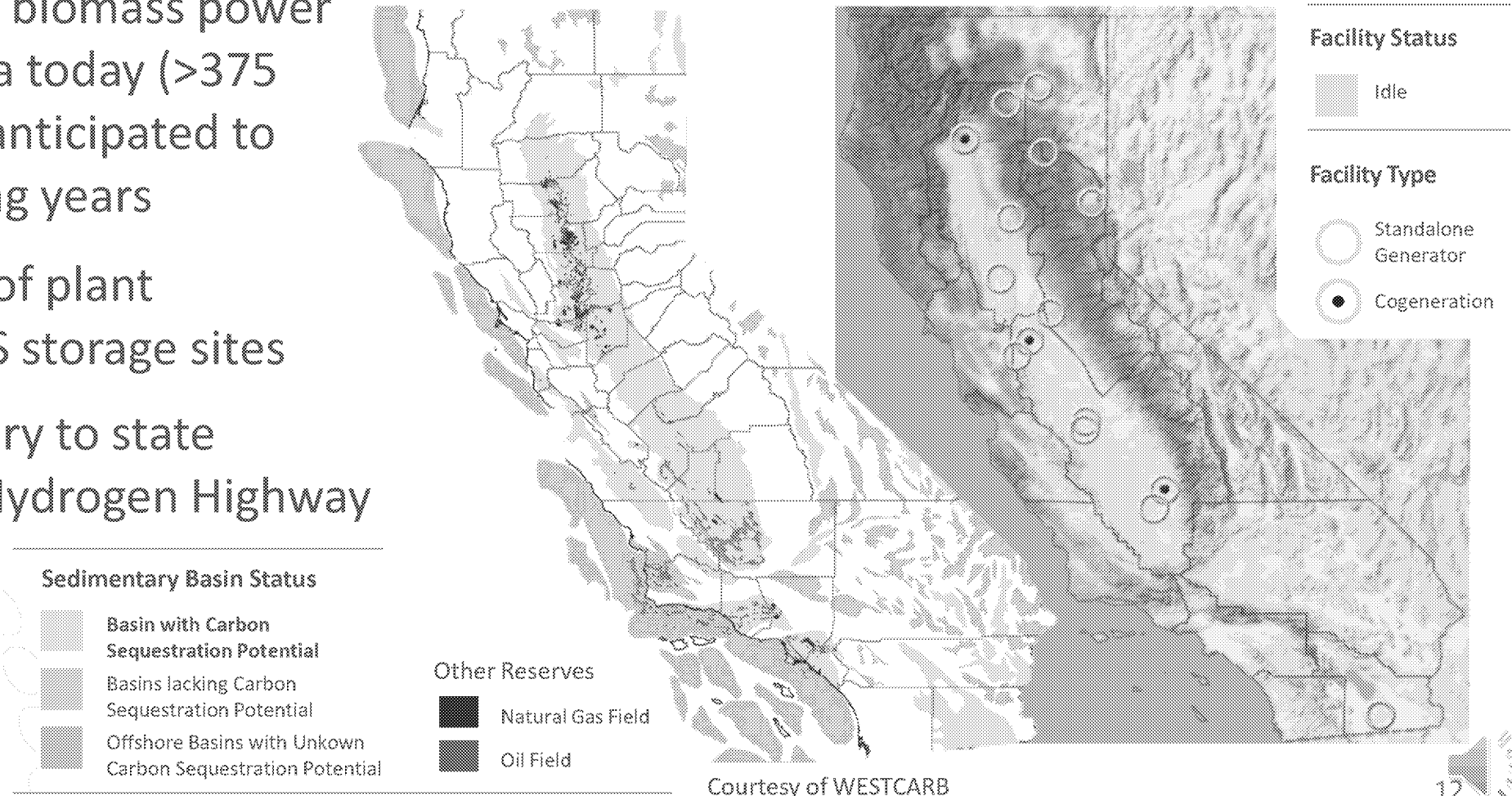


Courtesy of the California Energy Commission

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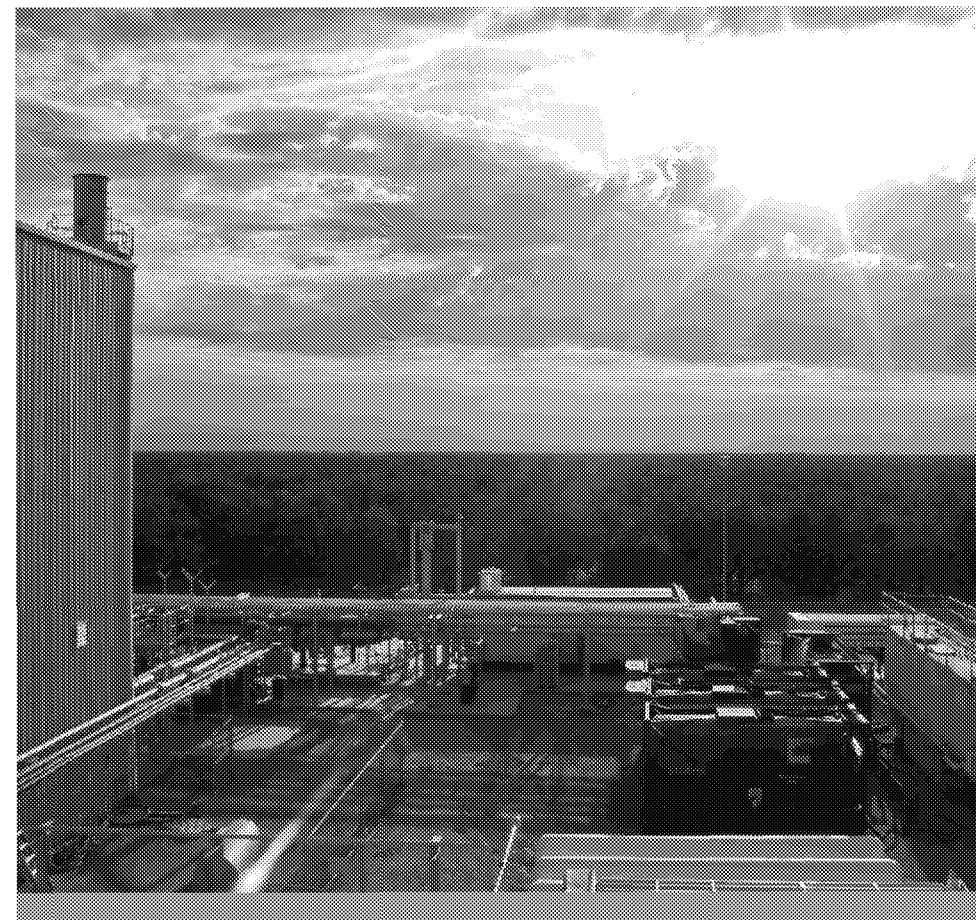
# CNE | POTENTIAL FOR BioCCS IN CALIFORNIA

- More than 15 idle biomass power plants in California today (>375 MW), with more anticipated to close in the coming years
- Excellent overlay of plant locations with CCS storage sites
- Suitable for delivery to state refineries or the Hydrogen Highway



# CNE I COMMUNITY BENEFITS

- Revitalization of existing biomass plants
- Elimination of criteria pollutant and CO<sub>2</sub> greenhouse gas emissions
- Reduction of open field burning of agricultural
- Supports decarbonization of California's transportation sector
  - Hydrogen from CNE plants removes ~3 lbs of CO<sub>2</sub> from the atmosphere for every mile driven
- Helps address tree mortality and wild fire crisis in the state
- A net water producer, with the ability to desalinate brackish water in the Central Valley
- Absolute necessity to meet the world's goal of less than 2 °C global temperature rise



# CES DEPLOYMENT I

## ENVIRONMENTAL IMPACT

- CES plans to deploy a fleet of CNE plants across California by retrofitting existing, idled biomass facilities
- First plants will be deployed in the Central Valley; CES has site control for the first four plants to be deployed by 2025
- Significant fuel production and environmental benefits for the state by replicating and scaling CNE plants

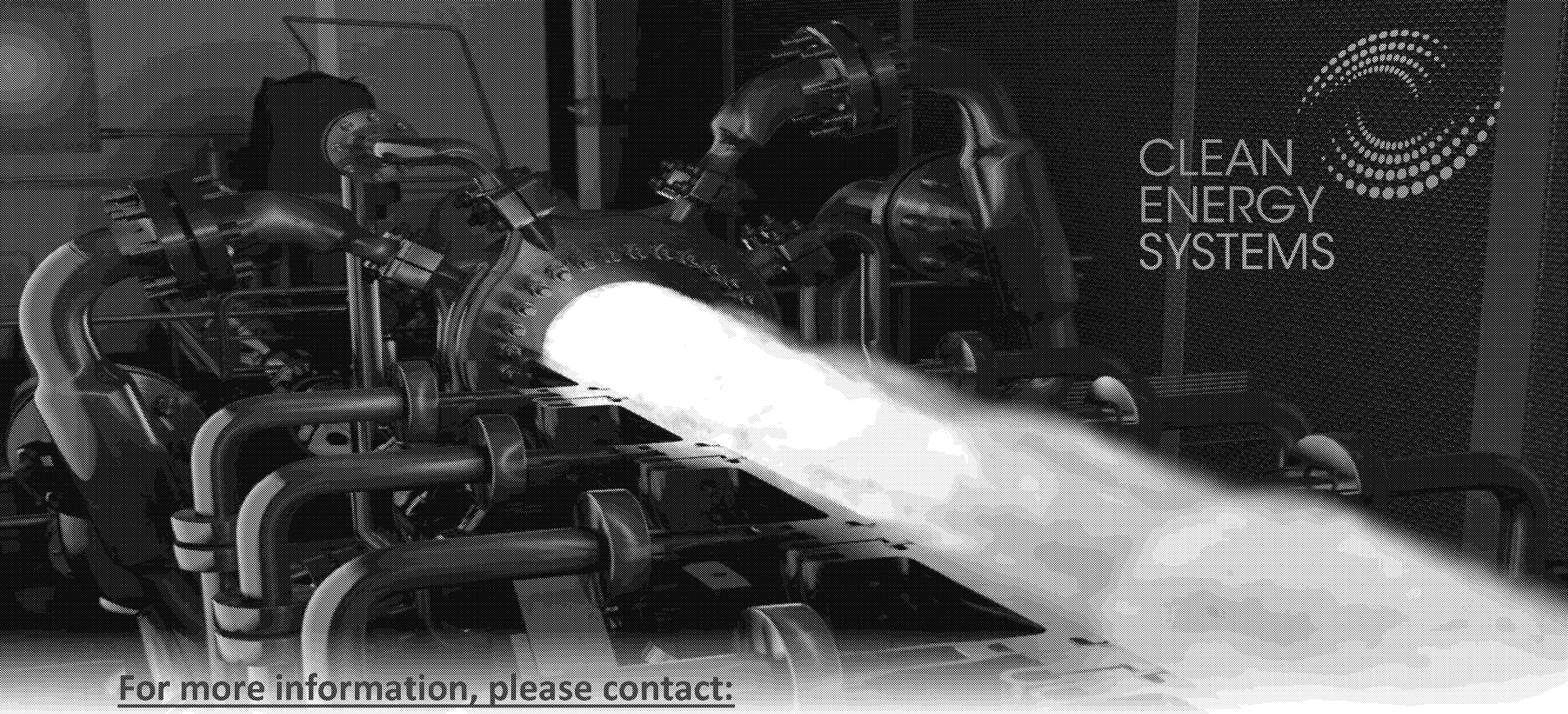
	First Four CNE Plants	Future Potential
	2022-2025	2025+
<b>Fuel Production (tonne/day)</b>		
RH <sub>2</sub> Produced	33	425
<b>Emissions Avoided (tonne/yr)</b>		
CO <sub>2</sub> Captured & Avoided	1,300,000	16,200,000
NOx Avoided	2,400	29,900
Particulates Avoided	5,100	64,100



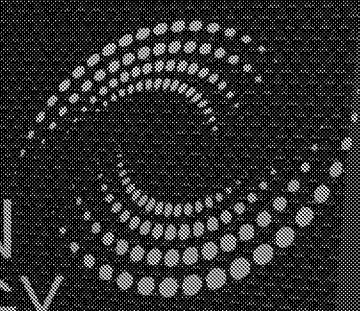


# CNE | SUMMARY & NEXT STEPS

- CES is working to develop the world's first carbon negative energy plants in California
  - Currently in project development of first two project sites
    - Plants will capture and permanently sequester 1 million tons of CO<sub>2</sub> per year (~950k metric tonne/yr)
  - Front-end engineering kicked off for major equipment (gasifier, hydrogen separation/processing, etc.)
  - Class VI CO<sub>2</sub> storage permit application submitted to EPA, currently under review with positive feedback
  - Tier 2 pathway for inclusion in California's Low Carbon Fuel Standard (LCFS) program submitted
- Next steps include securing feed and offtake agreements, conducting detailed engineering and permitting activities, and securing project financing
  - Secure feedstock supply and renewable electricity and hydrogen off-take agreements (in progress)
  - Contract vendors for key equipment blocks to secure fixed-price contracts (gasifier, oxygen supply, and hydrogen separation/liquefaction); same for all project sites
  - Kick off financing activities for first project sites, e.g. state-issued tax-exempt bonds
  - Work with EPA to secure Class VI injection permit (pre-construction) and develop and submit application for CARB Sequestration Site Permanence Certification



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For more information, please contact:

Keith L. Pronske, President and CEO  
[KLPrnske@CleanEnergySystems.com](mailto:KLPrnske@CleanEnergySystems.com)

Office: +1 916-638-7967

Or visit us at: [www.CleanEnergySystems.com](http://www.CleanEnergySystems.com)

